

$$I(J^P) = \frac{1}{2}(0^-)$$

K_S^0 MEAN LIFE

For earlier measurements, beginning with BOLDT 58B, see our our 1986 edition, Physics Letters **170B** 130 (1986).

OUR FIT is described in the note on "Fits for K_L^0 CP-Violation Parameters" in the K_L^0 Particle Listings.

VALUE (10^{-10} s)	EVTS	DOCUMENT ID	TECN	COMMENT
0.8935±0.0008 OUR NEW UNCHECKED FIT		$[(0.8934 \pm 0.0008) \times 10^{-10}$ s OUR 1998 FIT]		

0.8940±0.0009 OUR AVERAGE

0.8971±0.0021		BERTANZA	97	NA31
0.8941±0.0014±0.0009		SCHWINGEN...	95	E773 Δm free, $\phi_{+-} = \phi_{SW}$
0.8929±0.0016		GIBBONS	93	E731
0.8920±0.0044	214k	GROSSMAN	87	SPEC
0.881 ± 0.009	26k	ARONSON	76	SPEC
0.8924±0.0032		¹ CARITHERS	75	SPEC
0.8937±0.0048	6M	GEWENIGER	74B	ASPK
0.8958±0.0045	50k	² SKJEGGESTAD	72	HBC
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.905 ± 0.007		³ ARONSON	82B	SPEC
0.867 ± 0.024	2173	⁴ FACKLER	73	OSPK
0.856 ± 0.008	19994	⁵ DONALD	68B	HBC
0.872 ± 0.009	20000	^{5,6} HILL	68	DBC
0.866 ± 0.016		⁵ ALFF-...	66B	OSPK
0.843 ± 0.013	5000	⁵ KIRSCH	66	HBC

¹ CARITHERS 75 value is for $m_{K_L^0} - m_{K_S^0}$. $\Delta m = 0.5301 \pm 0.0013$. The Δm dependence of the total decay rate (inverse mean life) is $\Gamma(K_S^0) = [(1.122 \pm 0.004) + 0.16(\Delta m - 0.5348)/\Delta m] 10^{10}/s$, or, in terms of meanlife $\tau_S = 0.8913 \pm 0.0032 - 0.238(\Delta m - 0.5348)$ where Δm and τ_S are in units of 10^{10}hs^{-1} and 10^{-10}s respectively.

² HILL 68 has been changed by the authors from the published value (0.865 ± 0.009) because of a correction in the shift due to η_{+-} . SKJEGGESTAD 72 and HILL 68 give detailed discussions of systematics encountered in this type of experiment.

³ ARONSON 82 find that K_S^0 mean life may depend on the kaon energy.

⁴ FACKLER 73 does not include systematic errors.

⁵ Pre-1971 experiments are excluded from the average because of disagreement with later more precise experiments.

⁶ HILL 68 has been changed by the authors from the published value (0.865 ± 0.009) because of a correction in the shift due to η_{+-} . SKJEGGESTAD 72 and HILL 68 give detailed discussions of systematics encountered in this type of experiment.

K_S^0 DECAY MODES

Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
$\Gamma_1 \pi^+ \pi^-$	$(68.61 \pm 0.28) \%$	S=1.2
$\Gamma_2 \pi^0 \pi^0$	$(31.39 \pm 0.28) \%$	S=1.2
$\Gamma_3 \pi^+ \pi^- \gamma$	$[a,b] (1.78 \pm 0.05) \times 10^{-3}$	
$\Gamma_4 \gamma \gamma$	$(2.4 \pm 0.9) \times 10^{-6}$	
$\Gamma_5 \pi^+ \pi^- \pi^0$	$(3.2 \pm 1.2) \times 10^{-7}$	
$\Gamma_6 3\pi^0$	$< 1.4 \times 10^{-5}$	CL=90%
$\Gamma_7 \pi^\pm e^\mp \nu_e$	$[c] (7.2 \pm 1.4) \times 10^{-4}$	
$\Gamma_8 \pi^\pm \mu^\mp \nu_\mu$	$[c]$	
$\Delta S = 1$ weak neutral current (S1) modes		
$\Gamma_9 \mu^+ \mu^-$	$S1 < 3.2 \times 10^{-7}$	CL=90%
$\Gamma_{10} e^+ e^-$	$S1 < 1.4 \times 10^{-7}$	CL=90%
$\Gamma_{11} \pi^0 e^+ e^-$	$S1 < 1.1 \times 10^{-6}$	CL=90%

- [a] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [b] See the Particle Listings below for the energy limits used in this measurement.
- [c] The value is for the sum of the charge states or particle/antiparticle states indicated.

CONSTRAINED FIT INFORMATION

An overall fit to 3 branching ratios uses 17 measurements and one constraint to determine 2 parameters. The overall fit has a $\chi^2 = 16.5$ for 16 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

$$\begin{array}{c|c} x_2 & -100 \\ \hline & x_1 \end{array}$$

K_S^0 DECAY RATES

$\Gamma(\pi^\pm e^\mp \nu_e)$	Γ_7
8.1 ± 1.6	

VALUE (10^6 s^{-1})	EVTS	DOCUMENT ID	TECN	COMMENT	
8.1 ± 1.6	75	7 AKHMETSHIN 99	CMD2	Tagged K_S^0 using $\phi \rightarrow K_L^0 K_S^0$	

• • • We do not use the following data for averages, fits, limits, etc. • • •

7.50 ± 0.08	⁸ PDG	98	
seen	BURGUN	72	HBC $K^+ p \rightarrow K^0 p \pi^+$
9.3 ± 2.5	AUBERT	65	HLBC $\Delta S = \Delta Q$, CP cons. not assumed

⁷ AKHMETSHIN 99 is from a measured branching ratio $B(K_S^0 \rightarrow \pi e \nu_e) = (7.2 \pm 1.4) \times 10^{-4}$ and $\tau_{K_S^0} = (0.8934 \pm 0.0008) \times 10^{-10}$ s.

⁸ PDG 98 from K_L^0 measurements, assuming that $\Delta S = \Delta Q$ in K^0 decay so that $\Gamma(K_S^0 \rightarrow \pi^\pm e^\mp \nu_e) = \Gamma(K_L^0 \rightarrow \pi^\pm e^\mp \nu_e)$.

$\Gamma(\pi^\pm \mu^\mp \nu_\mu)$

Γ_8

<u>VALUE</u> (10^6 s $^{-1}$)	<u>DOCUMENT ID</u>		
5.25 ± 0.07	⁹ PDG	98	

• • • We do not use the following data for averages, fits, limits, etc. • • •

<u>VALUE</u> (10^6 s $^{-1}$)	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.6861 ± 0.0028 OUR FIT				Error includes scale factor of 1.2.
0.671 ± 0.010 OUR AVERAGE				

0.670 ± 0.010 3447 ¹⁰ DOYLE 69 HBC $\pi^- p \rightarrow \Lambda K^0$
 0.70 ± 0.08 COLUMBIA 60B HBC
 0.68 ± 0.04 CRAWFORD 59B HBC

• • • We do not use the following data for averages, fits, limits, etc. • • •

<u>VALUE</u> (10^6 s $^{-1}$)	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.740 ± 0.024		¹⁰ ANDERSON	62B	HBC
10 Anderson result not published, events added to Doyle sample.				

$\Gamma(\pi^+ \pi^-)/\Gamma(\pi^0 \pi^0)$

Γ_1/Γ_2

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
2.186 ± 0.028 OUR FIT				Error includes scale factor of 1.2.
2.197 ± 0.026 OUR AVERAGE				

2.11 ± 0.09 1315 EVERHART 76 WIRE $\pi^- p \rightarrow \Lambda K^0$
 2.169 ± 0.094 16k COWELL 74 OSPK $\pi^- p \rightarrow \Lambda K^0$
 2.16 ± 0.08 4799 HILL 73 DBC $K^+ d \rightarrow K^0 pp$
 2.22 ± 0.10 3068 ¹¹ ALITTI 72 HBC $K^+ p \rightarrow \pi^+ p K^0$
 2.22 ± 0.08 6380 MORSE 72B DBC $K^+ n \rightarrow K^0 p$
 2.10 ± 0.11 701 NAGY 72 HLBC $K^+ n \rightarrow K^0 p$
 2.22 ± 0.095 6150 ¹³ BALTAY 71 HBC $K p \rightarrow K^0$ neutrals
 2.282 ± 0.043 7944 ¹⁴ MOFFETT 70 OSPK $K^+ n \rightarrow K^0 p$
 2.10 ± 0.06 3700 MORFIN 69 HLBC $K^+ n \rightarrow K^0 p$

• • • We do not use the following data for averages, fits, limits, etc. • • •

2.12 ± 0.17	267	¹² BOZOKI	69	HLBC
2.285 ± 0.055	3016	¹⁴ GOBBI	69	OSPK $K^+ n \rightarrow K^0 p$

¹¹ The directly measured quantity is $K_S^0 \rightarrow \pi^+ \pi^- / \text{all } K^0 = 0.345 \pm 0.005$.

¹²NAGY 72 is a final result which includes BOZOKI 69.

¹³The directly measured quantity is $K_\zeta^0 \rightarrow \pi^+ \pi^- / \text{all } \bar{K}^0 = 0.345 \pm 0.005$.

¹⁴ MOFFETT 70 is a final result which includes GOBBI 69.

$$\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$$

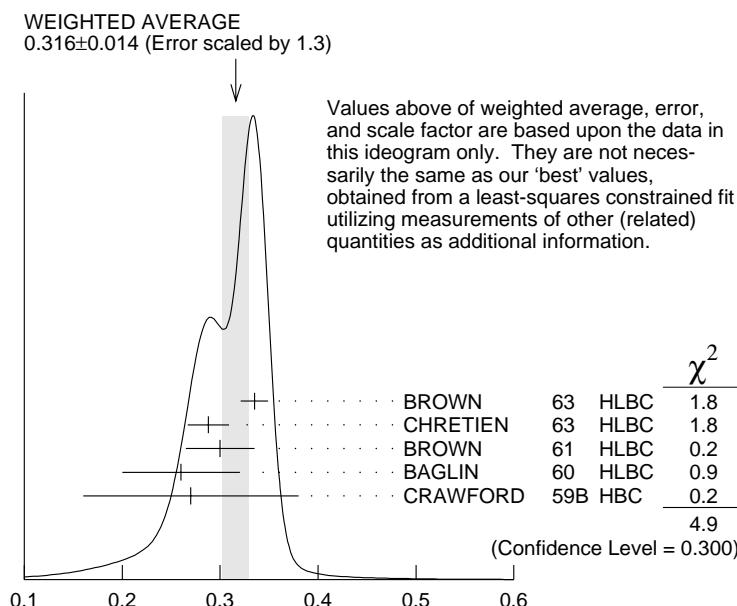
$$\Gamma_2/\Gamma$$

VALUE EVTS DOCUMENT ID TECN

0.3139 ± 0.0028 OUR FIT Error includes scale factor of 1.2.

0.316 ±0.014 OUR AVERAGE Error includes scale factor of 1.3. See the ideogram below.

0.335 \pm 0.014	1066	BROWN	63	HLBC
0.288 \pm 0.021	198	CHRETIEN	63	HLBC
0.30 \pm 0.035		BROWN	61	HLBC
0.26 \pm 0.06		BAGLIN	60	HLBC
0.27 \pm 0.11		CRAWFORD	59B	HBC



$$\Gamma(\pi^0 \pi^0)/\Gamma_{\text{total}}$$

$$\Gamma(\pi^+ \pi^- \gamma) / \Gamma(\pi^+ \pi^-)$$

$$\Gamma_3/\Gamma_1$$

VALUE (units 10⁻³) *EVTS* *DOCUMENT ID* *TECN* *COMMENT*

2.60 ± 0.08 OUR AVERAGE

2.56 ± 0.09	1286	RAMBERG	93	E731	p_γ	>50 MeV/c
2.68 ± 0.15		¹⁵ TAUREG	76	SPEC	p_γ	>50 MeV/c
2.8 ± 0.6		¹⁶ BURGUN	73	HBC	p_γ	>50 MeV/c
3.3 ± 1.2	10	WEBBER	70	HBC	p_γ	>50 MeV/c
no ratio given	27	BELLOTTI	66	HBC	p_γ	>50 MeV/c

• • • We do not use the following data for averages, fits, limits, etc. • • •

7.10 ± 0.22	3723	RAMBERG	93	E731	$p_\gamma > 20$ MeV/c
3.0 ± 0.6	29	¹⁷ BOBISUT	74	HLBC	$p_\gamma > 40$ MeV/c

¹⁵ TAUREG 76 find direct emission contribution < 0.06 , CL = 90%.

¹⁶ BURGUN 73 estimates that direct emission contribution is 0.3 ± 0.6 .

¹⁷ BOBISUT 74 not included in average because p_γ cut differs. Estimates direct emission contribution to be 0.5 or less, CL = 95%.

$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$

Γ_4/Γ

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
2.4 ± 0.9		35	¹⁸ BARR	95B NA31	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
2.2 ± 1.1		16	¹⁹ BARR	95B NA31	
< 13	90		BALATS	89 SPEC	
2.4 ± 1.2		19	BURKHARDT	87 NA31	
< 133	90		BARMIN	86 XEBC	
< 200	90		VASSERMAN	86 CALO	$\phi \rightarrow K_S^0 K_L^0$
< 400	90	0	BARMIN	73B HLBC	
< 710	90	0	²⁰ BANNER	72B OSPK	
< 2000	90	0	MORSE	72B DBC	
< 2200	90	0	²⁰ REPELLIN	71 OSPK	
< 21000	90	0	²⁰ BANNER	69 OSPK	

¹⁸ BARR 95B quotes this as the combined BARR 95B + BURKHARDT 87 result after rescaling BURKHARDT 87 to use same branching ratios and lifetimes as BARR 95B.

¹⁹ BARR 95B result is calculated using $B(K_L \rightarrow \gamma\gamma) = (5.86 \pm 0.17) \times 10^{-4}$.

²⁰ These limits are for maximum interference in $K_S^0 - K_L^0$ to 2γ 's.

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$

Γ_5/Γ

VALUE (units 10^{-7})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
3.2 ± 1.2 OUR AVERAGE					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
2.5 $\pm 1.3 \pm 0.5$		500k	²¹ ADLER	97B CPLR	
4.8 $\pm 2.2 \pm 1.1$			²² ZOU	96 E621	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
4.1 $\pm 2.5 \pm 0.5$			²³ ADLER	96E CPLR	Sup. by ADLER 97B
3.9 $\pm 5.4 \pm 0.9$			²⁴ THOMSON	94 E621	Sup. by ZOU 96
< 490	90		²⁵ BARMIN	85 HLBC	
< 850	90		METCALF	72 ASPK	

²¹ ADLER 97B find the CP-conserving parameters $\text{Re}(\lambda) = (28 \pm 7 \pm 3) \times 10^{-3}$, $\text{Im}(\lambda) = (-10 \pm 8 \pm 2) \times 10^{-3}$. They estimate $B(K_S^0 \rightarrow \pi^+\pi^-\pi^0)$ from $\text{Re}(\lambda)$ and the K_L^0 decay parameters. See also ANGELOPOULOS 98C.

²² ZOU 96 is from the measured quantities $|\rho_{+-0}| = 0.039^{+0.009}_{-0.006} \pm 0.005$ and $\phi_\rho = (-9 \pm 18)^\circ$.

²³ ADLER 96E is from the measured quantities $\text{Re}(\lambda) = 0.036 \pm 0.010^{+0.002}_{-0.003}$ and $\text{Im}(\lambda)$ consistent with zero. Note that the quantity λ is the same as ρ_{+-0} used in other footnotes.

²⁴ THOMSON 94 calculates this branching ratio from their measurements $|\rho_{+-0}| = 0.035^{+0.019}_{-0.011} \pm 0.004$ and $\phi_\rho = (-59 \pm 48)^\circ$ where $|\rho_{+-0}| e^{i\phi_\rho} = A(K_S^0 \rightarrow \pi^+ \pi^- \pi^0, I=2)/A(K_L^0 \rightarrow \pi^+ \pi^- \pi^0)$.

²⁵ BARMIN 85 assumes that *CP*-allowed and *CP*-violating amplitudes are equally suppressed.

$\Gamma(3\pi^0)/\Gamma_{\text{total}}$

Violates *CP* conservation.

VALUE (units 10^{-5})	CL%	EVTS	DOCUMENT ID	TECN
< 1.4 (CL = 90%)		[$< 0.37 \times 10^{-4}$ (CL = 90%) OUR 1998 BEST LIMIT]		
< 1.4	90	7M	ACHASOV	99D SND

• • • We do not use the following data for averages, fits, limits, etc. • • •

< 1.9	90	17300	26 ANGELOPO...	98B CPLR
< 3.7	90		BARMIN	83 HLBC
< 43	90		BARMIN	73 HLBC

²⁶ ANGELOPOULOS 98B is from $\text{Im}(\eta_{000}) = -0.05 \pm 0.12 \pm 0.05$, assuming $\text{Re}(\eta_{000}) = \text{Re}(\epsilon) = 1.635 \times 10^{-3}$ and using the value $B(K_L^0 \rightarrow \pi^0 \pi^0 \pi^0) = 0.2112 \pm 0.0027$.

Γ_6/Γ

$\Gamma(\pi^\pm e^\mp \nu_e)/\Gamma_{\text{total}}$

Γ_7/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID	TECN	COMMENT
7.2 ± 1.4	75	AKHMETSHIN 99	CMD2	Tagged K_S^0 using $\phi \rightarrow K_L^0 K_S^0$

$\Gamma(\mu^+ \mu^-)/\Gamma_{\text{total}}$

Γ_9/Γ

Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined with electromagnetic interaction.

VALUE (units 10^{-5})	CL%	DOCUMENT ID	TECN
< 0.032	90	GJESDAL	73 ASPK

• • • We do not use the following data for averages, fits, limits, etc. • • •

< 14	90	BOHM	69 OSPK
< 0.7	90	HYAMS	69B OSPK
< 22	90	27 STUTZKE	69 OSPK
< 7	90	BOTT-...	67 OSPK

²⁷ Value calculated by us, using 2.3 instead of 1 event, 90% CL.

$\Gamma(e^+ e^-)/\Gamma_{\text{total}}$

Γ_{10}/Γ

Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined with electromagnetic interaction.

VALUE (units 10^{-7})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
< 1.4	90	0	ANGELOPO... 97	CPLR	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
< 28	90	0	BLICK	94 CNTR	Hyperon facility
< 100	90		BARMIN	86 XEBC	
< 1100	90		BITSADZE	86 CALO	
< 3400	90		BOHM	69 OSPK	

$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$ Γ_{11}/Γ

Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined with electromagnetic interaction.

<u>VALUE (units 10^{-6})</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
< 1.1	90	0	BARR	93B NA31
<45	90		GIBBONS	88 E731

 CP VIOLATION IN $K_S \rightarrow 3\pi$

Written 1996 by T. Nakada (Paul Scherrer Institute) and L. Wolfenstein (Carnegie-Mellon University).

The possible final states for the decay $K^0 \rightarrow \pi^+ \pi^- \pi^0$ have isospin $I = 0, 1, 2$, and 3 . The $I = 0$ and $I = 2$ states have $CP = +1$ and K_S can decay into them without violating CP symmetry, but they are expected to be strongly suppressed by centrifugal barrier effects. The $I = 1$ and $I = 3$ states, which have no centrifugal barrier, have $CP = -1$ so that the K_S decay to these requires CP violation.

In order to see CP violation in $K_S \rightarrow \pi^+ \pi^- \pi^0$, it is necessary to observe the interference between K_S and K_L decay, which determines the amplitude ratio

$$\eta_{+-0} = \frac{A(K_S \rightarrow \pi^+ \pi^- \pi^0)}{A(K_L \rightarrow \pi^+ \pi^- \pi^0)} . \quad (1)$$

If η_{+-0} is obtained from an integration over the whole Dalitz plot, there is no contribution from the $I = 0$ and $I = 2$ final states and a nonzero value of η_{+-0} is entirely due to CP violation.

Only $I = 1$ and $I = 3$ states, which are $CP = -1$, are allowed for $K^0 \rightarrow \pi^0 \pi^0 \pi^0$ decays and the decay of K_S into $3\pi^0$ is an unambiguous sign of CP violation. Similarly to η_{+-0} , η_{000} is defined as

$$\eta_{000} = \frac{A(K_S \rightarrow \pi^0 \pi^0 \pi^0)}{A(K_L \rightarrow \pi^0 \pi^0 \pi^0)} . \quad (2)$$

If one assumes that CPT invariance holds and that there are no transitions to $I = 3$ (or to nonsymmetric $I = 1$ states), it can be shown that

$$\begin{aligned} \eta_{+-0} &= \eta_{000} \\ &= \epsilon + i \frac{\text{Im } a_1}{\text{Re } a_1}. \end{aligned} \quad (3)$$

With the Wu-Yang phase convention, a_1 is the weak decay amplitude for K^0 into $I = 1$ final states; ϵ is determined from CP violation in $K_L \rightarrow 2\pi$ decays. The real parts of η_{+-0} and η_{000} are equal to $\text{Re}(\epsilon)$. Since currently-known upper limits on $|\eta_{+-0}|$ and $|\eta_{000}|$ are much larger than $|\epsilon|$, they can be interpreted as upper limits on $\text{Im}(\eta_{+-0})$ and $\text{Im}(\eta_{000})$ and so as limits on the CP -violating phase of the decay amplitude a_1 .

CP-VIOLATION PARAMETERS IN K_S^0 DECAY

$$\text{Im}(\eta_{+-0})^2 = \Gamma(K_S^0 \rightarrow \pi^+ \pi^- \pi^0, \text{CP-violating}) / \Gamma(K_L^0 \rightarrow \pi^+ \pi^- \pi^0)$$

CPT assumed valid (i.e. $\text{Re}(\eta_{+-0}) \simeq 0$).

VALUE	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.23	90	601	²⁸ BARMIN	85	HLBC
<1.2	90	192	BALDO-...	75	HLBC
<0.71	90	148	MALLARY	73	OSPK $\text{Re}(A) = -0.05 \pm 0.17$
<0.66	90	180	JAMES	72	HBC
<1.2	90	99	JONES	72	OSPK
<0.12	90	384	METCALF	72	ASPK
<1.2	90	99	CHO	71	DBC
<1.0	90	98	JAMES	71	HBC Incl. in JAMES 72
<1.2	95	50	²⁹ MEISNER	71	HBC CL=90% not avail.
<0.8	90	71	WEBBER	70	HBC
<0.45	90		BEHR	66	HLBC
<3.8	90	18	ANDERSON	65	HBC Incl. in WEBBER 70

²⁸ BARMIN 85 find $\text{Re}(\eta_{+-0}) = (0.05 \pm 0.17)$ and $\text{Im}(\eta_{+-0}) = (0.15 \pm 0.33)$. Includes events of BALDO-CEOLIN 75.

²⁹ These authors find $\text{Re}(A) = 2.75 \pm 0.65$, above value at $\text{Re}(A) = 0$.

$$\text{Im}(\eta_{+-0}) = \text{Im}(A(K_S^0 \rightarrow \pi^+ \pi^- \pi^0, \text{CP-violating}) / A(K_L^0 \rightarrow \pi^+ \pi^- \pi^0))$$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$-0.002 \pm 0.009^{+0.002}_{-0.001}$	500k	30 ADLER	97B CPLR	

• • • We do not use the following data for averages, fits, limits, etc. • • •

$-0.002 \pm 0.018 \pm 0.003$	137k	31 ADLER	96D CPLR	Sup. by ADLER 97B
$-0.015 \pm 0.017 \pm 0.025$	272k	32 ZOU	94 SPEC	

30 ADLER 97B also find $\text{Re}(\eta_{+-0}) = -0.002 \pm 0.007^{+0.004}_{-0.001}$. See also ANGELOPOULOS 98C.

31 The ADLER 96D fit also yields $\text{Re}(\eta_{+-0}) = 0.006 \pm 0.013 \pm 0.001$ with a correlation $+0.66$ between real and imaginary parts. Their results correspond to $|\eta_{+-0}| < 0.037$ with 90% CL.

32 ZOU 94 use theoretical constraint $\text{Re}(\eta_{+-0}) = \text{Re}(\epsilon) = 0.0016$. Without this constraint they find $\text{Im}(\eta_{+-0}) = 0.019 \pm 0.061$ and $\text{Re}(\eta_{+-0}) = 0.019 \pm 0.027$.

$$\text{Im}(\eta_{000})^2 = \Gamma(K_S^0 \rightarrow 3\pi^0) / \Gamma(K_L^0 \rightarrow 3\pi^0)$$

CPT assumed valid (i.e. $\text{Re}(\eta_{000}) \simeq 0$). This limit determines branching ratio $\Gamma(3\pi^0)/\Gamma_{\text{total}}$ above.

VALUE	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<0.1	90	632	33 BARMIN	83 HLBC
<0.28	90		34 GJESDAL	74B SPEC
<1.2	90	22	BARMIN	73 HLBC

33 BARMIN 83 find $\text{Re}(\eta_{000}) = (-0.08 \pm 0.18)$ and $\text{Im}(\eta_{000}) = (-0.05 \pm 0.27)$. Assuming *CPT* invariance they obtain the limit quoted above.

34 GJESDAL 74B uses $K_2\pi$, $K_{\mu 3}$, and $K_{e 3}$ decay results, unitarity, and *CPT*. Calculates $|\eta_{000}| = 0.26 \pm 0.20$. We convert to upper limit.

$$\text{Im}(\eta_{000}) = \text{Im}(A(K_S^0 \rightarrow \pi^0 \pi^0 \pi^0) / A(K_L^0 \rightarrow \pi^0 \pi^0 \pi^0))$$

$K_S^0 \rightarrow \pi^0 \pi^0 \pi^0$ violates *CP* conservation, in contrast to $K_S^0 \rightarrow \pi^+ \pi^- \pi^0$ which has a *CP*-conserving part.

VALUE	EVTS	DOCUMENT ID	TECN
$-0.05 \pm 0.12 \pm 0.05$	17300	35 ANGELOPO... 98B	CPLR

35 ANGELOPOULOS 98B assumes $\text{Re}(\eta_{000}) = \text{Re}(\epsilon) = 1.635 \times 10^{-3}$. Without assuming *CPT* invariance, they obtain $\text{Re}(\eta_{000}) = 0.18 \pm 0.14 \pm 0.06$ and $\text{Im}(\eta_{000}) = 0.15 \pm 0.20 \pm 0.03$.

K_S^0 REFERENCES

ACHASOV	99D	PL B459 674	M.N. Achasov <i>et al.</i>	
AKHMETSHIN	99	PL B456 90	R.R. Akhmetshin <i>et al.</i>	(CMD-2 Collab.)
ANGELOPO...	98B	PL B425 391	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
ANGELOPO...	98C	EPJ C5 389	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
PDG	98	EPJ C3 1	C. Caso <i>et al.</i>	
ADLER	97B	PL B407 193	R. Adler <i>et al.</i>	(CPLEAR Collab.)
ANGELOPO...	97	PL B413 232	A. Angelopoulos <i>et al.</i>	(CPLEAR Collab.)
BERTANZA	97	ZPHY C73 629	L. Bertanza (PISA, CERN, EDIN, MANZ, ORSAY+)	
ADLER	96D	PL B370 167	R. Adler <i>et al.</i>	(CPLEAR Collab.)
ADLER	96E	PL B374 313	R. Adler <i>et al.</i>	(CPLEAR Collab.)
ZOU	96	PL B369 362	Y. Zou <i>et al.</i>	(RUTG, MINN, MICH)
BARR	95B	PL B351 579	G.D. Barr <i>et al.</i>	(CERN, EDIN, MANZ, LALO+)
SCHWINGEN...	95	PRL 74 4376	B. Schwingenheuer <i>et al.</i>	(EFI, CHIC+)
BLICK	94	PL B334 234	A.M. Blick <i>et al.</i>	(SERP, JINR)
THOMSON	94	PL B337 411	G.B. Thomson <i>et al.</i>	(RUTG, MINN, MICH)
ZOU	94	PL B329 519	Y. Zou <i>et al.</i>	(RUTG, MINN, MICH)
BARR	93B	PL B304 381	G.D. Barr <i>et al.</i>	(CERN, EDIN, MANZ, LALO+)
GIBBONS	93	PRL 70 1199	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
Also	97	PR D55 6625	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
RAMBERG	93	PRL 70 2525	E. Ramberg <i>et al.</i>	(FNAL E731 Collab.)
BALATS	89	SJNP 49 828	M.Y. Balats <i>et al.</i>	(ITEP)
		Translated from YAF 49	1332.	
GIBBONS	88	PRL 61 2661	L.K. Gibbons <i>et al.</i>	(FNAL E731 Collab.)
BURKHARDT	87	PL B199 139	H. Burkhardt <i>et al.</i>	(CERN, EDIN, MANZ+)
GROSSMAN	87	PRL 59 18	N. Grossman <i>et al.</i>	(MINN, MICH, RUTG)
BARMIN	86	SJNP 44 622	V.V. Barmin <i>et al.</i>	(ITEP)
		Translated from YAF 44	965.	
BARMIN	86B	NC 96A 159	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
BITSADZE	86	PL 167B 138	G.S. Bitsadze, Y.A. Budagov	(CMNS, SOFI, SERP+)
PDG	86B	PL 170B 130	M. Aguilar-Benitez <i>et al.</i>	(CERN, CIT+)
VASSERMAN	86	JETPL 43 588	I.B. Vasserman <i>et al.</i>	(NOVO)
		Translated from ZETFP 43	457.	
BARMIN	85	NC 85A 67	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
Also	85B	SJNP 41 759	V.V. Barmin <i>et al.</i>	(ITEP)
		Translated from YAF 41	1187.	
BARMIN	83	PL 128B 129	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
Also	84	SJNP 39 269	V.V. Barmin <i>et al.</i>	(ITEP, PADO)
		Translated from YAF 39	428.	
ARONSON	82	PRL 48 1078	S.H. Aronson <i>et al.</i>	(BNL, CHIC, STAN+)
ARONSON	82B	PRL 48 1306	S.H. Aronson <i>et al.</i>	(BNL, CHIC, PURD)
Also	82B	PL 116B 73	E. Fischbach <i>et al.</i>	(PURD, BNL, CHIC)
Also	83	PR D28 476	S.H. Aronson <i>et al.</i>	(BNL, CHIC, PURD)
Also	83B	PR D28 495	S.H. Aronson <i>et al.</i>	(BNL, CHIC, PURD)
ARONSON	76	NC 32A 236	S.H. Aronson <i>et al.</i>	(WISC, EFI, UCSD+)
EVERHART	76	PR D14 661	G.C. Everhart <i>et al.</i>	(PENN)
TAUREG	76	PL 65B 92	H. Taureg <i>et al.</i>	(HEIDH, CERN, DORT)
BALDO...	75	NC 25A 688	M. Baldo-Ceolin <i>et al.</i>	(PADO, WISC)
CARITHERS	75	PRL 34 1244	W.C.J. Carithers <i>et al.</i>	(COLU, NYU)
BOBISUT	74	LNC 11 646	F. Bobisut <i>et al.</i>	(PADO)
COWELL	74	PR D10 2083	P.L. Cowell <i>et al.</i>	(STON, COLU)
GEWENIGER	74B	PL 48B 487	C. Geweniger <i>et al.</i>	(CERN, HEIDH)
GJESDAL	74B	PL 52B 119	S. Gjesdal <i>et al.</i>	(CERN, HEIDH)
BARMIN	73	PL 46B 465	V.V. Barmin <i>et al.</i>	(ITEP)
BARMIN	73B	PL 47B 463	V.V. Barmin <i>et al.</i>	(ITEP)
BURGUN	73	PL 46B 481	G. Burgun <i>et al.</i>	(SACL, CERN)
FACKLER	73	PRL 31 847	O. Fackler <i>et al.</i>	(MIT)
GJESDAL	73	PL 44B 217	S. Gjesdal <i>et al.</i>	(CERN, HEIDH)
HILL	73	PR D8 1290	D.G. Hill <i>et al.</i>	(BNL, CMU)
MALLARY	73	PR D7 1953	M.L. Mallary <i>et al.</i>	(CIT)
ALITTI	72	PL 39B 568	J. Alitti, E. Lesquoy, A. Muller	(SACL)
BANNER	72B	PRL 29 237	M. Banner <i>et al.</i>	(PRIN)
BURGUN	72	NP B50 194	G. Burgun <i>et al.</i>	(SACL, CERN, OSLO)
JAMES	72	NP B49 1	F. James <i>et al.</i>	(CERN, SACL, OSLO)
JONES	72	NC 9A 151	L.H. Jones <i>et al.</i>	(ILL)
METCALF	72	PL 40B 703	M. Metcalf <i>et al.</i>	(CERN, IPN, WIEN)

MORSE	72B	PRL 28 388	R. Morse <i>et al.</i>	(COLO, PRIN, UMD)
NAGY	72	NP B47 94	E. Nagy, F. Telbisz, G. Vesztregombi	(BUDA)
Also	69	PL 30B 498	G. Bozoki <i>et al.</i>	(BUDA)
SKJEGGEST...	72	NP B48 343	O. Skjeggestad <i>et al.</i>	(OSLO, CERN, SACL)
BALTAY	71	PRL 27 1678	C. Baltay <i>et al.</i>	(COLU)
Also	71	Thesis Nevis 187	W.A. Cooper	(COLU)
CHO	71	PR D3 1557	Y. Cho <i>et al.</i>	(CMU, BNL, CASE)
JAMES	71	PL 35B 265	F. James <i>et al.</i>	(CERN, SACL, OSLO)
MEISNER	71	PR D3 59	G.W. Meisner <i>et al.</i>	(MASA, BNL, YALE)
REPELLIN	71	PL 36B 603	J.P. Repellin <i>et al.</i>	(ORSAY, CERN)
MOFFETT	70	BAPS 15 512	R. Moffett <i>et al.</i>	(ROCH)
WEBBER	70	PR D1 1967	B.R. Webber <i>et al.</i>	(LRL)
Also	69	Thesis UCRL 19226	B.R. Webber	(LRL)
BANNER	69	PR 188 2033	M. Banner <i>et al.</i>	(PRIN)
BOHM	69	Thesis	Bohm	(AACH)
BOZOKI	69	PL 30B 498	G. Bozoki <i>et al.</i>	(BUDA)
DOYLE	69	Thesis UCRL 18139	J.C. Doyle	(LRL)
GOBBI	69	PRL 22 682	B. Gobbi <i>et al.</i>	(ROCH)
HYAMS	69B	PL 29B 521	B.D. Hyams <i>et al.</i>	(CERN, MPIM)
MORFIN	69	PRL 23 660	J.G. Morfin, D. Sinclair	(MICH)
STUTZKE	69	PR 177 2009	R.D. Stutzke <i>et al.</i>	(ILL)
DONALD	68B	PL 27B 58	R.A. Donald <i>et al.</i>	(LIVP, CERN, IPNP+)
HILL	68	PR 171 1418	D.G. Hill <i>et al.</i>	(BNL, CMU)
BOTT-...	67	PL 24B 194	M. Bott-Bodenhausen <i>et al.</i>	(CERN)
ALFF-...	66B	PL 21 595	C. Alff-Steinberger <i>et al.</i>	(CERN)
BEHR	66	PL 22 540	L. Behr <i>et al.</i>	(EPOL, MILA, PADO, ORSAY)
BELLOTTI	66	NC 45A 737	E. Bellotti <i>et al.</i>	(MILA, PADO)
KIRSCH	66	PR 147 939	L. Kirsch, P. Schmidt	(COLU)
ANDERSON	65	PRL 14 475	J.A. Anderson <i>et al.</i>	(LRL, WISC)
AUBERT	65	PL 17 59	B. Aubert <i>et al.</i>	(EPOL, ORSAY)
BROWN	63	PR 130 769	J.L. Brown <i>et al.</i>	(LRL, MICH)
CHRETIEN	63	PR 131 2208	M. Chretien <i>et al.</i>	(BRAN, BROW, HARV+)
ANDERSON	62B	CERN Conf. 836	G. Anderson <i>et al.</i>	(LRL)
BROWN	61	NC 19 1155	J.L. Brown <i>et al.</i>	(MICH)
BAGLIN	60	NC 18 1043	C. Baglin <i>et al.</i>	(EPOL)
COLUMBIA	60B	Rochester Conf. 727	M. Schwartz <i>et al.</i>	(COLU)
CRAWFORD	59B	PRL 2 266	F.S. Crawford <i>et al.</i>	(LRL)
BOLDT	58B	PRL 1 150	E. Boldt, D.O. Caldwell, Y. Pal	(MIT)

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BIRGE	60	Rochester Conf. 601	R.W. Birge <i>et al.</i>	(LRL, WISC)
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